

**U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY**

HEARING CHARTER

Ending Our Oil Addiction: Are Advanced Vehicles and Fuels the Answer?

**Monday, June 5, 2006
10:00am - 12:00pm
Naperville Municipal Center
400 South Eagle Street
Naperville, IL 60540**

1. Purpose

On June 5, 2006, the Subcommittee on Energy of the House Committee on Science will hold a field hearing titled *Assessing Progress in Advanced Technologies for Vehicles and Fuels*. The hearing will examine progress made in the development of advanced on-board vehicle and fuel technologies for passenger vehicles that can increase fuel economy or reduce oil consumption through fuel substitution.

2. Witnesses

- **Dr. Daniel Gibbs** is President of the General Biomass Company in Evanston, IL. His research interests are in enzymes that digest cellulose, paper waste utilization and cellulosic ethanol production.
- **Mr. Philip G. Gott** is Director for Automotive Custom Solutions at Global Insight, a major economic and financial forecasting firm.
- **Mr. Deron Lovaas** is the Vehicles Campaign Director for the Natural Resources Defense Council.
- **Mr. Jerome Hinkle** is the Vice President for Policy and Government Affairs with the National Hydrogen Association.
- **Dr. James F. Miller** is Manager of the Electrochemical Technology Program at Argonne National Laboratory. He is an authority on energy storage and energy conversion technologies, with a particular expertise in fuel cells and batteries.
- **Mr. Al Weverstad** is the Executive Director for Mobile Emissions and Fuel Efficiency at the General Motors Public Policy Center. He began his engineering career in 1971 with General Motors' Pontiac Motor and Marine Engine Divisions.

3. Overarching Questions

The Committee hearing will address the following questions:

1. What progress has been made towards realizing the Hydrogen Economy since the 2002 field hearing?
2. What new vehicle technologies and fuel choices might be available in the near future that could increase U.S. energy independence?
3. What technical and economic obstacles might limit or block the availability in the marketplace of cars built with new technologies or using advanced fuels?
4. What should the federal government be doing (or not doing) through research and development spending and through the implementation of energy policies to encourage the commercialization of, and demand for new vehicle technologies and fuels?

4. Brief Overview

Currently, the U.S. consumes roughly 20 million barrels of oil daily. Of that, 40 percent is used to fuel cars and trucks at a cost to consumers of more than \$250 billion per year. By 2020, oil consumption is forecast by the Energy Information Administration to grow by nearly 40 percent, and our dependence on imports is projected to rise to more than 60 percent. A 10 percent reduction in energy use from cars and light trucks (achieved by introducing an alternative fuel or improving fuel economy) would result in displacing nearly 750,000 barrels of oil per day. A similar percentage reduction in petroleum energy use from heavy-duty trucks and buses would displace around 200,000 and 10,000 barrels per day, respectively. Both the federal government and industry are funding programs designed to create affordable vehicles that would use less or no gasoline or petroleum-based diesel fuel, including programs on hydrogen-powered fuel cells, biofuels, and hybrid vehicle technologies.

The federal government will spend over \$200 million in fiscal year (FY) 2006 on such research and development (R&D) programs.

One focus of federal programs to increase fuel economy, and part of the President's Advanced Energy Initiative announced this year, is R&D to advance hybrid vehicles. Hybrid vehicles, such as the Toyota Prius or the Ford Escape, use batteries and an electric motor, along with a gasoline engine, to improve vehicle performance and to reduce gasoline consumption, particularly in city driving conditions. Plug-in hybrid vehicles are a more advanced version of today's hybrid vehicles. Plug-in hybrid vehicles require larger batteries and the ability to charge those batteries overnight using an ordinary electric outlet. Such a change would shift a portion of the automotive energy demand from oil to the electricity grid. (Little electricity in the U.S. is generated using oil.) Additional R&D is needed to increase the reliability and durability of batteries, to significantly extend their lifetimes, and to reduce their size and weight.

Fuel substitution R&D focuses on two fuel types: hydrogen and biofuels. Hydrogen gas is considered by many experts to be a promising fuel in the long term, particularly in the transportation sector. When used as a fuel, its only combustion byproduct is water vapor. If

hydrogen can be produced economically from energy sources that do not release carbon dioxide into the atmosphere—from renewable sources such as wind power or solar power, from nuclear power, or possibly from coal with carbon sequestration—then the widespread use of hydrogen as a fuel could make a major contribution to reducing the greenhouse gas emissions. On-board hydrogen storage remains a major technical hurdle to the development of practical hydrogen-powered passenger vehicles.

Biofuels, such as ethanol and biodiesel, are made from plant material, and therefore can result in decreased greenhouse gas emissions, since the carbon dioxide emitted when biofuel is burned is mostly offset by the carbon dioxide absorbed during plant growth. Biofuel R&D is directed toward developing low-cost methods of industrial-scale production, which includes advanced biotechnology and bioengineering of both plants and microbes (to help break down the plants into usable materials).

On May 24, 2005, the House of Representatives passed H.R. 5427, the appropriations bill for FY 2007 that includes funding for these programs. In the bill:

- the overall Vehicle Technology subaccount received \$173 million, a reduction of 6 percent from last year's level. Within this amount, Hybrid and Electric Propulsion, part of the President's Advanced Energy Initiative, received \$50 million, up 14 percent from last year.
- the Hydrogen Technology subaccount received \$196 million, an increase of 26 percent from last year's level; about 42 percent of this is directed to the FreedomCAR program for hydrogen vehicles.
- the Biomass Technology subaccount, part of the President's Advanced Energy Initiative received \$150 million, a 65 percent increase, most of which is directed toward biofuel development.

Historically, both the Hydrogen subaccount and the Biomass subaccount have been heavily earmarked, with 27 percent of Hydrogen funding and 57 percent of biomass funding diverted to Congressionally directed projects in FY 2006.

5. Background

On June 24, 2002, the Energy Subcommittee of the House Committee on Science held a field hearing at Northern Illinois University in Naperville, IL titled *Fuel Cells: The Key to Energy Independence?*¹ The hearing focused on developments in hydrogen fuel cell R&D and provided

¹ The Science Committee and its Subcommittees have held numerous hearings on the use of hydrogen since the announcement of the FreedomCAR Initiative by then-Secretary of Energy Spencer Abraham on January 9, 2002. The FreedomCAR program was centered on fuel cell vehicles that use hydrogen as fuel. The full committee held the following hearings:

- February 7, 2002 - Full Committee *Hearing on The Future of DOE's Automotive Research Programs*
- April 2, 2003 - Full Committee *Mark-Up of HR 238; Energy Research, Development, Demonstration, and Commercial Application Act of 2003*
- March 5, 2003 - Full Committee *Hearing on The Path to a Hydrogen Economy*
- March 3, 2004 - Full Committee *Hearing Reviewing the Hydrogen Fuel and FreedomCAR Initiatives*

The Energy Subcommittee held the following hearings:

a broad overview of fuel cells for all applications, not just transportation. Witnesses at that hearing were unanimous in their assessment that current technical approaches to on-board storage of hydrogen gas require too large a volume to be practical in vehicles. Solving the storage problem was identified as one of the toughest technical hurdles for the use of hydrogen as a transportation fuel. Their assessment was echoed subsequently by expert reports from the American Physical Society and the National Academy of Sciences.

Since that 2002 field hearing, the federal government has focused more attention on the development of advanced vehicle and fuel technologies. In his 2003 State of the Union Address, President Bush announced a \$1.2 billion Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells. From fiscal 2004 to 2006, over \$625 million has been allocated to hydrogen research in Department of Energy (DOE), over 40 percent of which was directed to the FreedomCAR vehicle program. The White House Office of Science and Technology Policy established the interagency Hydrogen Research and Development Task Force to coordinate the eight Federal agencies that fund hydrogen-related research and development. The Energy Policy Act of 2005 authorized a broad spectrum of research programs related to advanced on-board vehicle, hydrogen and liquid fuel technologies.

With the release of his FY 2007 budget request, the President announced his Advanced Energy Initiative. This initiative provides for a 22 percent increase in funding for clean energy technology research at DOE. Two major goals of the initiative are to reduce demand through greater use of technologies that improve efficiency, including plug-in hybrid technology; and to change the way Americans fuel their vehicles by expanding use of alternative fuels from domestically-produced biomass and by continuing development of fuel cells that use hydrogen from domestic feedstocks.

Hydrogen

The widespread adoption of hydrogen as a transportation fuel has the potential to reduce or eliminate air pollution generated by cars and trucks, but the source of the hydrogen is important. Hydrogen must be produced from hydrogen-bearing compounds, like water or natural gas, and that requires energy—and, unlike gasoline, more energy is always required to produce it than is recovered when hydrogen is burned or used in a fuel cell. Hydrogen has the potential to reduce America's dependence on foreign oil, but how much it would reduce dependence depends on what energy source would be used to generate hydrogen gas in the first place.

If hydrogen can be produced economically from energy sources that do not release carbon dioxide into the atmosphere—from renewable sources such as wind power or solar power, from nuclear power, or possibly from coal with carbon sequestration—then the widespread use of

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- June 26, 2002 - Subcommittee on Energy *Hearing on FreedomCar: Getting New Technology into the Marketplace*
 - June 24, 2002 - Subcommittee on Energy *Field Hearing Fuel Cells and the Hydrogen Future*
 - July 20, 2005 - Joint Hearing - Subcommittee on Energy and Subcommittee on Research - *Fueling The Future: On The Road To The Hydrogen Economy*.

hydrogen as a fuel could make a major contribution to reducing the emission of greenhouse gases.

A fuel cell is a device for converting hydrogen and oxygen into electricity and water. Fuel cells have been used extensively for electrical power in space missions, including Apollo and Space Shuttle missions. In cars, the electricity would then be used to run electric motors to drive the wheels. Technological breakthroughs have reduced the cost and size of fuel cells, making them promising sources of power for automobiles, but fuel cells are still far too costly for everyday use.

Furthermore, there are research challenges with the fuel itself. To serve as automobile fuel, hydrogen must be stored on-board, but storing pure hydrogen at room temperature requires a large volume. Researchers are therefore working on developing complex fuels that can be stored compactly but can release pure hydrogen as needed. A final obstacle to widespread use is the need for new fueling infrastructure. To make hydrogen-fueled automobiles practical, hydrogen must be as easily available as gasoline, requiring a widespread network of hydrogen fuel stations.

Virtually all major foreign and domestic automakers have produced hydrogen-powered concept and demonstration vehicles. For example, General Motors has produced several fuel cell vehicle prototypes, including the Hy-wire, Sequel and AUTOnomy concept cars and the HydroGen3 minivan. The minivan is being used in demonstration fleets, but at a cost of more than \$1 million per vehicle, these vehicles are far from ready for the market. There are fourteen hydrogen fueling stations in the U.S, including one that General Motors and Shell opened in Washington, D.C., as part of a joint demonstration program. There are nine hydrogen stations in California, which has allowed Honda to offer one of its fuel cell cars, the Honda FCX, to a family in Southern California to demonstrate its day-to-day use.

Biofuels

Rising oil prices in recent years have heightened interest in a variety of alternative sources of liquid fuels. At present, two biologically-derived fuel forms, ethanol and biodiesel, are used in the United States to supplement supplies of conventional gasoline and diesel. Although biofuel combustion releases carbon dioxide, growing the agricultural products to create ethanol consumes carbon dioxide. Both ethanol and biodiesel can be readily blended with conventional gasoline or diesel, respectively, although the fraction of either biofuel is limited by compatibility with some materials in the fuel system and engine, or by gelling of the fuel mixture at low temperatures.

Ethanol is a renewable fuel produced by fermenting sugars from biological products. Many different sources can provide the fermentation feedstock, such as trees and grasses and municipal solid waste, but in the United States, ethanol is now most commonly made from corn. Research is focused on developing feedstocks other than corn, particularly feedstocks that are not otherwise used for food. This requires the development of enzymes to digest what is otherwise waste plant material—stalks, leaves and husks—into fermentable sugars. Known as cellulosic ethanol, ethanol produced using both digestion and fermentation can use more parts of a plant and can expand the variety of economically viable feedstock for the production of ethanol. This

would allow introduction of a wide variety of other feedstocks, including woody plants like willow and fast growing switchgrass. As with all ethanol, compatibility with the current fuel infrastructure is not perfect: transportation and energy content are two concerns. Ethanol's detractors argue that because ethanol can absorb water, it cannot be transported in gasoline pipelines, and use of carriers other than pipelines may complicate gasoline substitution on a national scale. Additionally, ethanol is lower in energy per gallon than gasoline, so consumer expectations about how far they can drive on a gallon of fuel need to be managed accordingly.

Ethanol, in use for years in the Midwest as a gasoline additive for improving octane levels, is now finding wider use by replacing an older octane-boosting additive found to contaminate drinking water. Ethanol can, however, serve as a primary ingredient in vehicle fuel. One blend of ethanol and gasoline is E85, 85 percent ethanol and 15 percent gasoline. Many automobile manufacturers produce Flex Fuel Vehicles (FFV's) that can run on either E85 or ordinary gasoline, a capability that does not significantly add to vehicle price. General Motors, DaimlerChrysler, Ford, and Nissan all produce FFV cars and trucks. (Some analysts point out that most of these FFVs were produced by manufacturers because they get a credit against their corporate fuel economy requirements, rather than because of any consumer or market demand for the fuel flexibility option.)

Ethanol fuels are also in widespread use abroad. Brazil instituted a policy to encourage flexible fuel cars during the energy crisis of the 1970s, and between 1983 and 1988 more than 88 percent of cars sold annually were running on a blend of ethanol and gasoline. Flex fuel car sales fell after withdrawal of the subsidy, but even today, fuel in Brazil has a minimum of 25 percent ethanol. Most ethanol in Brazil is produced from sugar cane, a much more efficient process than producing ethanol from corn, as is done in the United States.

Biodiesel is a renewable fuel that can be used in diesel engines, but is produced from vegetable oils and animal fats instead of petroleum. Using biodiesel instead of petroleum diesel reduces emissions of pollutants such as carbon monoxide, particulates, and sulfur. Biodiesel-petroleum diesel blends, with up to 20 percent biodiesel, can be used in nearly all diesel equipment. Higher biodiesel percentage blends may require specialized engines, delivery, and storage technology. Biodiesel is used in the fleets of many school districts, transit authorities, national parks, public utility companies, and garbage and recycling companies.

E85 and biodiesel fuel stations are scattered around the country. There are 637 E85 fuel stations in the U.S., with 102 in Illinois, and there are 362 biodiesel stations in the U.S., with 11 in Illinois. Compared to the more than 200,000 standard gasoline stations, these biofuels are still very difficult to find. The Alternative Fuels Data Center provides maps indicating the locations of fueling stations with advanced fuels.²

Plug-in Hybrids

Hybrid vehicles combine batteries and an electric motor, along with a gasoline engine, to improve vehicle performance and to reduce gasoline consumption. Conventional hybrid electric

² See <http://www.eere.energy.gov/afdc>.

vehicles recharge their batteries by capturing the energy released during braking or through a generator attached to the combustion engine. These energy management techniques mean that these cars dissipate less of the energy contained in their fuel as waste heat. Nearly 200,000 hybrid passenger vehicles, such as the Toyota Prius or the Ford Escape, were sold in the U.S. from 2000 to 2004. Over 40 transit agencies in North America use hybrid buses. There are approximately 700 hybrid buses in regular service in North America, with another 400 planned deliveries through 2006.

Plug-in hybrid vehicles are a more advanced version of today's hybrid vehicles. They involve larger batteries and the ability to charge those batteries when parked using an ordinary electric outlet. Unlike today's hybrids, plug-in hybrids are able to drive for extended periods solely on battery power, thus moving some of the energy consumption from the gasoline tank to the electric grid (batteries are typically charged overnight) and moving some of the emissions from the tailpipe to the power plant (where, in theory, they are more easily controlled).

Because most Americans commute less than 40 miles a day, plug-in hybrids operable for 40 miles on an overnight charge from the electric grid could reduce U.S. gasoline consumption significantly. The potential for oil savings is related to how far a plug-in hybrid can travel solely on battery power. The electricity used to charge the batteries overnight would be generated from domestic sources (only 3 percent of the electricity used in the United States is generated from oil) and that electricity would primarily be consumed at night when demand is low.

President Bush, as part of his Advanced Energy Initiative, has established the goal of developing technology that would enable plug-in hybrids to travel up to 40 miles on battery power alone. Plug-in hybrids could benefit consumers because of their greater fuel economy and the relatively low cost of energy from the electric grid. Some proponents of plug-in hybrids claim that consumers will be able to recharge their batteries overnight at gasoline-equivalent cost of \$1 per gallon.

While plug-in hybrid vehicles offer many advantages, high initial costs prevent widespread commercial application. Specialty conversion kits are available to upgrade an ordinary hybrid to a plug-in hybrid—although in very limited quantities and at high cost (about \$10,000 per kit). Many component technologies, particularly the batteries, will need to achieve significant cost reductions and improvements in reliability before plug-in hybrids are truly attractive to consumers at mass-market scale. Car companies are reluctant to invest in these technologies without demonstrable consumer demand. R&D is needed to increase the reliability and durability of batteries, to significantly extend their lifetimes, and to reduce their size and weight.

Because batteries on board a plug-in hybrids are recharged by plugging the vehicle into an outlet, these vehicles do not need new types of fuel stations. The large batteries used in plug-in hybrids might also be used to provide power back to the electric power grid. A fleet of plug-in hybrids could offer regulatory services (keeping voltages steady, etc.) to a modernized grid. Advocates say that such vehicle-to-grid transmissions could benefit individual car owners by allowing them to sell the use of their energy storage capacity to grid operators.

The development and widespread use of plug-in hybrid vehicles could act as a stepping stone toward hydrogen-based transportation and fuel cell vehicles, because the electric motors and power control technologies that are required for plug-in hybrid cars would also be useful in fuel cell vehicles.

The first plug-in hybrid produced by a major automaker, the DaimlerChrysler Sprinter van, has been delivered to U.S. customers for test purposes. Many other plug-in hybrids are being tested in prototype form by small firms and individuals.

6. Witness Questions

Dr. Daniel Gibbs

1. How widely available is ethanol today, and how many cars can use it?
2. What are the obstacles to expanding the variety of feedstocks available for conversion to ethanol? Are these hurdles mainly market failures and other economic barriers or are they technical in nature?
3. What is the largest technical hurdle for each of the following fuels: Corn ethanol, biodiesel, cellulosic ethanol? Does the current federal research agenda adequately address these technical barriers? What actions would most rapidly overcome these technical barriers?
4. Some advocates suggest that biofuels should substitute for 25 percent or more of the Nation's transportation fuel use. Are there market or other barriers that policy might overcome to accelerate realization of the 25 percent biofuels goal?

Mr. Philip Gott and Mr. Deron Lovaas

1. The auto industry in recent years has generally used technological improvements to increase performance instead of fuel efficiency. What would be required to lead automakers to apply technology advancements to improving fuel economy?
2. What hurdles must hybrids, flex fuel, and hydrogen-powered vehicles clear before the automobile industry, industry analysts, and the automotive press accept these technologies and consumers buy them? How more or less likely is it that these radically new technologies – fuel cells, electric drive trains, or significant battery storage capabilities, for example – will be incorporated into cars rather than incremental innovations to internal combustion engines?

Mr. Jerome Hinkle

1. Many experts indicate that on-board hydrogen storage is the major bottleneck facing realization of the hydrogen economy. What research paths look the most promising for solving the on-board storage problem?
2. What technical barriers in the production and distribution need to be overcome to permit hydrogen to fuel a quarter of the cars on the highway?
3. What are the tradeoffs between centralized and distributed hydrogen production for fueling the transportation infrastructure?

Dr. James Miller

1. What are the two most significant technical obstacles to making hydrogen-powered fuel cell vehicles affordable and practical to use? What are those obstacles for plug-in hybrids? How soon is significant progress likely to be made on removing each of the obstacles you mention? Can either hydrogen fuel cell vehicles or plug-in hybrids advance rapidly enough to be a more practical alternative to reducing energy consumption and pollution than making continuing improvements in the internal combustion engine would be?
2. Batteries need to be more durable, more rapidly chargeable, have longer lifetimes, and reduced size and weight if plug-in hybrids are to become practical. How are those traits related to one another and are there trade-offs between these performance parameters? Which are the easiest to address? Which of these contribute most significantly to cost?

Mr. Al Weverstad

1. What are the significant cost and technical differences between a flex fuel engine and a conventional engine? Are there specific challenges to incorporating flex fuel technologies in plug-in hybrid electric vehicles? Why aren't these technologies incorporated in every car sold?
2. What technologies would automakers adopt first to enable passenger vehicle to have a fuel economy significantly higher than available today, say 60 miles per gallon? What technologies would be used to hit a 45 mile per gallon target? What technologies would be used to hit a 35 mile per gallon target?
3. Are there gaps in the government's advanced vehicles and fuels research and development portfolio that could help with the more rapid adoption of new technologies? Do the Department of Energy programs have the correct balance between research and technology demonstration?